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Understanding diversity shifts by characterising the community

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Summary
Increases in the species richness of the entire North Sea have been reported in the literature, and are commonly attributed to the rapid warming of this region. However, the North Sea is an extremely heterogeneous environment, with significant differences between the south and the north, and between seasons. In this paper we show how fine-scale analysis of regional-scale diversity trends can reveal a substantially different picture of change and its drivers. We use catch data from the International Bottom Trawl Survey (IBTS) to investigate biodiversity and community changes around the North Sea at the scale of ICES statistical rectangles (~50km). During the winter quarter, significant species richness increases were widespread, sea bottom temperatures (SBT) were better predictors of lusitanian change rates and boreal changes were better linked to surface temperatures (SST). In the summer quarter, boreal species numbers had mainly declined or remained stable, while southern species richness increased mostly in the north. Evidence suggest that warming is partly responsible for the shift towards a lusitanian dominated community.

Introduction
The rapid warming of the North Sea has driven profound community changes, ranging from increases in species richness (Hiddink and Hofstede, 2008) to northward distribution shifts (Dulvy et.al, 2008). However, the North Sea is an extremely heterogeneous environment, with significant differences between the south and the north, and between seasons: lumping such diverse environments together appears naive. Additional factors like fishing pressure, changes in trophic interaction and certain species traits may influence the response rates observed in a community. For example, studies on observed geographical distribution shifts of the North Sea fish assemblage estimated that within a 25 year period, 15 of 36 species had shifted their center of distribution latitudinally in relation to warming, and the shifts ranged from 48 to 403 km in distance (Perry et.al, 2005). Nonetheless, understanding species distribution changes is crucial to facilitate successful management strategies, especially in a world governed by political borders. Studying how species ranges will response to the new climate will give us an opportunity to adapt fishing or conservation strategies in a more effective way, which maximizes resource expenditure and minimizes the inevitable damage to come. We show how a fine-scale analysis of regional-scale community responses can reveal a substantially different picture of change and its drivers. Three types of community responses are examined: species richness trends, range changes and mean size of the community's species. In order to improve our understanding of community changes, biogeographic trait groups will be applied and response rates will be compared to thermal variability.

Materials and Methods
We used catch data from the International Bottom Trawl Survey (IBTS) between 1983 to 2013 for the quarter one (January to March) survey and 1992 to 2013 for the quarter three (July to September) survey. The study was performed at an ICES statistical rectangles (SR; ~55km), covering 152 species for the first quarter and 140 for the third quarter. Species richness change rates were modelled using generalized additive models (log link and poison observation error distribution), with number of species observed in a statistical square in a given year as the response variable, a linear dependence on time (year) for each square and a spline smoother on the number of hauls performed per-square-per-year to correct for sampling intensity. Probability of occurrence, as a proxy of distributtional change, and the community's proportion of boreal and lusitanian species were estimated through generalized linear models (logit link with binomial family). The formula included year and SR as main effects nested within SR. Lastly, the

estimated community responses were modelled using various models including: couple interaction interactions between average SST/SBT, their rates of change and depth of the SR.

Results and Discussion

Overall increasing species richness was found to be better modelled with SST variability, however; lusitanian and boreal species richness changes were not. An increasing number of lusitanian species are successfully reaching and stablishing in the warmer and warming northern North Sea, possibly migrating to deeper waters during winter to avoid colder surface waters(Figure 1A). As SBT warm up across the North Sea, suitable overwintering habitat increases allowing these species to expand southward towards shallower waters. In contrast, boreal species were not expected to be highly affected by the warming winter temperatures alone, as they tolerate warmer temperatures during summer. However, it is likely that the warming temperatures, combined with an increasing trophic pressure from lusitanians, are triggering declines in the number of boreal species in the northwest (Figure 1B). In response, boreal species staying within the North Sea are shifting in two directions: eastward, drawn by the cooling SST off Norway, and southward to shallower and cooling waters, although probably unable to persist during the warm summer.

Warming during quarter three is detrimental for boreal species (Figure 1D), however; no thermal variable alone significantly modelled their species richness decline. We suggest that warming temperatures increase stress over the cold water species, deteriorating their demographic traits and making them more susceptible to other disturbances such as, fishing pressure, competition or predation. This makes their decline stochastic and more difficult to predict. Nonetheless, boreal richness and occurrence probability rates seemed to remain more stable along the British coast which could be attributed to a slowly warming SST and cooling SBT trend linked to a reduced influx from the English Channel since mid-90s (Dulvy et.al, 2008). On the other hand, lusitanian richness is significantly increasing throughout, but most rapidly in the northern North Sea since their richness was already high in the southern half (Figure 1C).

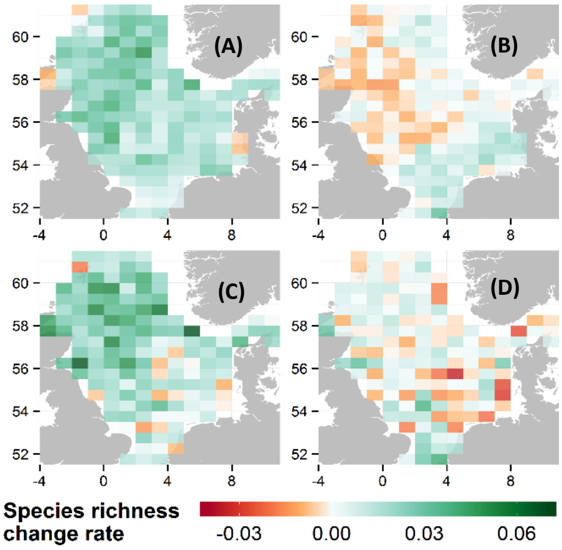

Figure. 1 Change rates of lusitanian (A & C) and boreal (B & D) species richness for quarter one (top) and three (bottom) in the North Sea.

In summary, strong evidence is presented indicating a shift to a lusitanian-species dominated community, heavily influenced by winter thermal changes and depth. Boreal species are being heavily affected by thermal dynamics, and their richness may have increased in the south, we predict strong boreal declines in the North Sea in combination with the positive North Atlantic Oscillation period, which probably reverse the cooling pattern around the southern North Sea during summer. In order to account for total biodiversity loss, species richness along the Norwegian Sea shelf should be analyzed.

References

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